Investigation of Sedimentary Processes on Millennial Timescales in an Accretionary Continental Margin Setting

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LONG-TERM GOALS

The focus of my work in the first two phases of STRATAFORM has been oriented toward identifying the sedimentary processes that act together to produce the characteristic deposits of the uppermost seabed (< 50 cm depth) over short timescales (100-y and less). Over centuries to millennia, sediment discharge, climate, and sea-level all change significantly, affecting the preserved record of sedimentary processes in the margin and the dominant processes responsible for acoustic stratigraphy observed in seismic profiles. The long-term goal of this project is to determine the millennial-scale sedimentary processes that are responsible for the development of acoustic stratigraphy and the characteristic signatures of these processes. A good understanding of the significance of reflectors imaged in the seabed is of critical importance to achieving the goals of the STRATAFORM program.

SCIENTIFIC OBJECTIVES

The focus of this two-year project is to document the sedimentary processes important on millennial timescales on the continental slope and how these processes are recorded in the sedimentary strata of continental margins. The specific objectives of this project are:

? to determine the rates of sedimentary processes on 1000-yr timescales.
? to document the stratigraphic signature of these processes in long cores.
? to provide high-resolution time and stratigraphic control for interpretation of acoustic stratigraphy.
? to determine the importance of submarine canyons in the sequestration of and the delivery to the deep sea of fluvial material.
? to document the Eel River dispersal system and finalize a sediment budget for the slope.

During this first year of the project, I focused on determining the stratigraphic signature of millennial-scale sedimentary processes as recorded in long cores, thereby providing ground truth to acoustic stratigraphic interpretations and on examining various sediment dispersal pathways in an effort to come to closure on the sediment budget.

APPROACH

Sediment cores (0.5-9 m in length) have been collected in slope, canyon and deep water regions to investigate processes that dominate on 100-1000 year time-scales. Work has been focused on

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analyzing cores collected during the past year, and in collecting additional cores in unsampled regions that are critical to achieving the goals outlined above. This past summer was the last field effort for this phase of my STRATAFORM research. In addition, I assessed the capabilities of unique long-coring technology to STRATAFORM goals. Rates of processes are being examined using longer-lived radiotracers pertinent to the longer timescales being examined (14C and limited 210Pb). Examination of sedimentary properties in longer cores and over longer timescales will be used to provide a more thorough understanding of those processes that leave their signature in the geologic record.

WORK COMPLETED

Two cruises have been completed this year (June and July) representing two major core collection efforts. The June cruise, jointly funded by ONR-MG&G and JOI, Inc., represented the first step in planning for long coring in support of STRATAFORM's long-term goals. This cruise, sampling off New Jersey on the French RV Marion-Dufresne II, allowed us to evaluate the capabilities of this ship to retrieve long (60-m) Calypso piston cores and was focused on core locations generated by a group of STRATAFORM scientists at the Deep Coring Meeting, which Greg Mountain and I held at the Skidaway Institute of Oceanography in October, 1998. This meeting incorporated input from all participants in the STRATAFORM program to identify scientific questions to be addressed by deep cores (30-200 m sub-bottom) in both STRATAFORM sites and to suggest locations for these cores. On this cruise, we collected 9 Calypso piston cores (2-37 m long), 4 box cores (0.4-0.9 m long) and 1 gravity core (4 m long).

The July cruise was multidisciplinary in nature and for my program focused on finalizing the shelf/slope sediment budget by sampling the lower slope and proximal basin plain between the Trinity and Eel Canyons, and sampling a depth transect along which the effect of biological mixing on radiochemical profiles will be quantified. Cores were sieved at selected depth intervals to identify organisms causing biological mixing, mixing rates will be calculated using 234Th and mixing signatures were imaged with x-radiography.

Because several cruises take place each fiscal year, core subsampling and sample analysis is an ongoing operation. The long piston cores collected from the Eel margin during this project have been subsampled and x-radiographed. 14C analyses to provide long-term accumulation rates in conjunction with textural analyses and core stratigraphy interpretation to provide ground-truth data for seismic interpretations are ongoing. Long cores are stored at the USGS in Menlo Park and their facilities are used for subsampling. Two subsampling trips were made to the USGS during this past year. Cores from the Marion Dufresne II cruise are archived in the ODP core repository at the Lamont-Doherty Earth Observatory and are presently being split and subsampled. One core collected from the Marion Dufresne II was analyzed by J. Locat in his laboratory at the Univ. de Laval.

Several meetings were attended to move the STRATAFORM deep-coring initiative forward. Greg Mountain and I attended the IMAGES planning meeting at the Fall AGU meeting in December 1998. This group schedules the coring operations of the Marion Dufresne II, and is the avenue for STRATAFORM's use of the vessel. In April, Jamie Austin, Greg Mountain and I presented the coring sites identified at the Deep Coring Meeting to the ODP Pollution Prevention and Safety

Panel, in the interest of using their expertise to avoid problems with these issues. Although no problems were identified, the presence of subsurface gas caused the PPSP to ask us to return when their shallow gas expert was available and we plan to make a final presentation later this year.

Laboratory analyses have concentrated on generating 14C ages and textural analyses of long cores. The AMS age dating technique is being used, necessitating the time-consuming task of picking 600-1000 forams from each sample interval. Additional cores from the mid-slope plateau and lower slope are being analyzed to provide adequate coverage of this important slope sedimentary environment and to constrain the sediment budget.

RESULTS

The Marion Dufresne II is a suitable vessel from which to collect long, undisturbed piston cores for the STRATAFORM program. We successfully retrieved ~35 m cores in muddy slope sediments, indicating that cores from the Eel margin in lengths of 40 m on the slope and 20 m on the shelf should be obtainable. Core integrity is good and a MST logger with laboratory facilities is available onboard.

In total, a suite of 145 cores has been collected to examine sedimentary processes on the Eel River continental slope. Twenty-five 14C dates have been obtained, which provide average long-term rates (1000-y timescale) in the range of 10-330 cm/103y. These rates are typically lower than those measured on 100-y timescales, as is frequently observed when these two timescales are compared, because the long-term rates incorporate more small erosional or hiatal events within their time frame of reference. In areas near actively deforming regions of the seabed, as evidenced by anticlinal or diapiric structures in seismic records, 14C ages indicate that there has been removal of the seabed by uplift and erosion. Linear ages in piston cores extrapolated to the surface indicate surface ages of 6,000-11,000 years BP in these areas. In contrast, cores from quiescent areas show linear rates that extrapolate to a reasonable surface age and that are in agreement with rates determined on Pb-210 timescales.

Sediment texture in long cores shows that the Eel margin responds rapidly to changes in base level, suggesting that narrow, sediment-rich, accretionary margins may not exhibit a lack of sediment supply during sea-level transgressions. As sea level has risen from 12,000 to 5,000 years ago, areas proximal to the river mouth have not exhibited a loss of coarse material as would be expected, but have coarsened toward the surface over the complete core record. In areas distal from the river mouth, fine-grained sediments have continued to accumulate over the past 8,000 years as well.

Over the past year, the slope sediment budget has been revised downward 5% based on new data from the outer mid-slope plateau (600-800 m water depth). Finalizing the budget awaits results of this summer's cruise to include accumulation on the lower slope and basin plain. At present, the budget reveals that the upper slope and mid-slope plateau contain 15% of the river's annual discharge; a combined budget for the shelf, upper slope and mid-slope plateau documents that 65% of the annual sediment load is not accounted for in these areas.

IMPACT/APPLICATIONS

The lack of closure in the sediment budget for the open slope re-emphasizes the importance of canyons as a major sink and/or conduit for fluvially derived material. The distribution of accumulation rates across the slope suggests that the slope is building up along the shelf break, where sediment is then remobilized and trapped on the mid-slope plateau. Sediment is also accumulating in the heads of canyons, where periodic downcanyon flows may deliver sediment to the deep sea. Processes typically associated with transitional stages of sea-level (i.e., direct supply of sediment to the slope and delivery of fluvial material to canyons) are actively occurring on the Eel River margin.

TRANSITIONS

High-resolution age control (on 1000-y timescales) and stratigraphic interpretations in long cores are being used by geotechnical research groups to better interpret their own observations and by geophysical groups to ground-truth their data. Shelf researchers are using my slope data to complement their data to gain a margin-wide perspective on the redistribution of fluvial material. Knowledge of the capabilities of the Marion Dufresne II will be used by the STRATAFORM community to further develop plans for deep coring within the program.

RELATED PROJECTS

The high-resolution time stratigraphy and sediment textural observations are critical ground-truth for M. Field's (USGS) acoustic stratigraphy determined from geophysical data. Field and I are presently identifying important reflectors in seismic profiles to target for further sedimentological analyses. H. Lee (USGS) and I have been working closely for the past five years, and plan to continue in our collaboration on the relationship between sedimentary processes and geotechnical properties. C. Sommerfield (USGS/WHOI) and I are cooperating closely to quantify long-term sediment accumulation rates and to develop the sediment budget for the shelf and slope. C. Nittrouer (UW) and I are collaboratively investigating canyon-head sedimentary processes. Information concerning the rates and patterns of sediment transport to and within the slope region are important as input to Pratson's (UNC) modeling efforts and D. Orange's (UCSC) studies of the influence of tectonics on sedimentation patterns.

PUBLICATIONS

1998 Rates and Products of Sedimentary Processes on 100-y and 1000-y Timescales in the Northern California Continental Margin (C. Alexander). 1998 Fall AGU Meeting, San Francisco, CA.

1999 Be as a Tracer of Flood Sedimentation on the Northern California Continental Margin (C.K. Sommerfield, C.A. Nittrouer and C.R. Alexander). Continental Shelf Research, 19:335-361.

1999 Spatial Variability in Sedimentary Processes on the Eel River Continental Slope (C. Alexander and A. Simoneau). Marine Geology, 154:243-254.